# Post-gel polymerization shrinkage strain evaluation of four light-activated composites using different curing modes

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## ABSTRACT

Background: One of the ways of minimizing polymerization shrinkage of light-activated composites is by applying short pulses of light energy, prepolymerization at low light intensity followed by final cure at high intensity (soft-start polymerization) or a combination of both. This study investigated the influence of different curing modes on the post-gel polymerization shrinkage strain of different light- activated composites.

Materials and methods: This study investigated the Post-Gel Polymerization Shrinkage Strain of two mm thick composite specimens after exposure to different curing modes. Parameters included six conventional curing modes: Control (C), Pulse Delay I (PDI), Pulse Delay II (PDII), Soft-start (SS), Pulse Cure I (PCI), and Pulse Cure II (PCII) plus three experimental curing modes of higher energy density: Prolonged low-intensity pulse cure mode (PLPC), Prolonged moderate-intensity pulse cure mode (PMPC) and Rapid high-intensity continues cure mode (RHCC) for each of the four different light-activated composite materials (Tetric Ceram, Heliomolar, Herculite XRV and Degufill Mineral).

Results: Statistical analysis of the data by using the one-way analysis of variance revealed that, there was a statistically significant difference for all the polymerization shrinkage strains with the composite type, curing mode and post-curing-time.

Conclusion: Light intensity reduction and elongation of the curing time combined with pulse activation and soft start polymerization (PLPC curing mode) resulted in significantly lower and gradual post-gel polymerization shrinkage strain for all the light-activated composites being tested

Key words: Post-gel polymerization, Light curing modes, Polymerization Shrinkage strain. J Bagh Coll Dentistry 2009; 21(2):14-17)

## INTRODUCTION

Modern advanced technology continues to develop improved resin composites. As a result of this, new resin composites have become widely used for many purposes in restorative dentistry. Although they are considered the best aesthetic direct restorative material [1], existing drawbacks include inferior wear resistance to that of amalgam, excessive polymerization shrinkage, incomplete conversion and cross-linking, and undesirable water-sorption [2]. The shrinkage of resin composites can be divided into two phases: the pre-gel and post-gel phase. The gel point is defined as the moment at which the material can no longer provide viscous flow to keep up with the curing contraction [3]. During pre-gel polymerization, the composite is able to flow and stress within the structure is relieved. Flow is thought to be the ability of molecules to slip into new orientations during the polymerization process [4].

When the cross-linking reaction becomes predominant, there is no longer the ability of individual polymer chains to slide. At this stage, usually denoted as the post-gel phase, the polymeric chains reach sufficient modulus of elasticity to develop a strong, rigid visco-elastic material. Any further composite shrinkage will generate mechanical stress in the restoration [5].

One way of minimizing polymerization shrinkage of light-activated composites is to allow flow through controlled polymerization during setting. This may be achieved by applying short pulses of light energy, prepolymerization at low light intensity followed by final cure at high intensity (soft-start polymerization) or a combination of both. Studies [6, 7] have shown that these polymerization modes result in smaller marginal gap, increased marginal integrity and improved material properties. The objective of this research was to investigate the influence of different curing modes on the post-gel polymerization shrinkage strain of four different light- activated composites.

## MATERIALS AND METHODS

A light-curing unit with programmable time and intensity (variable intensity polymerizer) (VIP Light, Bisco Inc., Schaumburg, Ill.; Spectrum 800, Dentsply/Caulk, Milford, Del.) was used as the light curing unit for all curing procedures later on. A digital light meter (Coltolux) (Coltène/Whaledent.com, France) was used to measure the light intensity delivered from the curing tip. Four different light-activated resin composite materials of A2 Vita shade were selected: Tetric Ceram (Ivoclar, Vivadent AG FL-9494 Schaan/Liechtenstein.Lot: E58102), Heliomolar (Ivoclar, Vivadent AG FL-9494 Schaan/Liechtenstein.Lot: C37535), Herculite XRV (SDS Kerr, 1717 West Collins Orange, CA 92867, U.S.A.Lot: 205466.Item No.:

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22860) and Degufill Mineral (Degussa-Hüls AG, Degussa Dental GmbH & Co. KG, Postfach 1364. D- 63403 Hanau, Germany.Lot: 0885). A stiff black rubber frame (inner diameter 8mm and height 2mm) (Iraqi construction) was used as a mold for the composite material. A glass slide (Blue star glass industries, Delhi, India) served as the base of the set-up. A foil electrical resistance strain gauge (Figure 1) (Tinsley Telcon Ltd, London, S. E.25, England)(gauge length 2mm, gauge factor 2.15, electrical resistance 120Ω) was attached to the flat glass surface. The excess composite material was extruded using pressure applied through the use of a cover slide. The surface tack of the composite was adequate to ensure adhesion between the strain gauge and the composite materials. The leads from the strain gauge were connected to a digital strain-monitoring device (DMD-21, Omega, England) initially balanced at zero by adjusting the course and fine adjustment bottoms. The parameters of the devise were adjusted (bridge volts: 2 volt; bridge mode ¼ and gauge factor 2.15).

The composite specimens were light polymerized using the nine different light-curing modes (Tables 1 & 2). During the light-polymerization process, shrinkage strain measurements were taken continuously every 10 seconds with the exception of PDI, where the first measurement was taken after three seconds. For PDI and PDII, readings were taken at 60-second intervals during the three-minute delay period. Post-light polymerization strain measurements were taken at 0 (end of photo curing), 1, 5, 10, 15, 20, 25, 30 and 60 minutes. Mean and standard deviation were calculated for each specific polymerization shrinkage strain. Statistical analysis procedure was not carried out for the data during light polymerization, because the time intervals that depend on the characteristic feature of each curing-mode. Data at only 0, 1, 5, and 60 minutes post-light polymerization was subjected to one-way ANOVA and Least significant difference (LSD)-test at significance level 0.05 to find any significant difference between each pair of polymerization shrinkage strains.

# RESULTS

Statistical analysis of the data by using the one-way analysis of variance revealed that, there is statistically very highly significant difference for all the polymerization shrinkage strains with the composite type, curing mode and post-curing-time. Mean polymerization shrinkage strain in micro-strain of the four different light-activated composites cured with the nine-different curing modes at the end of curing, 1-min post-curing, 5-min post-curing and 60-min post-curing is better summarized in Figures 2-5.

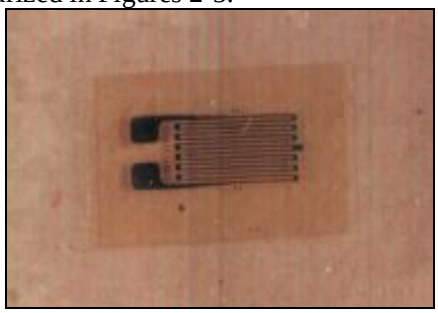

**Figure 1: A foil electrical resistance strain gauge 2 mm in length.**

**Table 1: The conventional different light-curing modes [8].**

| Light-curing mode | Regimen |
|---|---|
| Control (CC) | 400mW/cm2 (40 seconds) |
| Pulse Delay I (PDI) | 100mW/cm2→Delay→ 500mW/cm2 (3 seconds) (3 minutes) (30 seconds) |
| Pulse Delay II (PDII) | 200mW/cm2→Delay→ 500mW/cm2 (20 seconds) (3 minutes) (30 seconds) |
| Soft-start (SS) | 200mW/cm2 → 600mW/cm2 (10 seconds) (30 seconds) |
| Pulse Cure I (PCI) | 400 mW/cm2→Delay→ 400 mW/cm2→Delay→ 400 mW/cm2 (10 seconds) (10 seconds) (10 seconds) (10 seconds) (20 seconds) |
| Pulse Cure II (PCII) | 400 mW/cm2→Delay→ 400 mW/cm2 (20 seconds) (20 seconds) (20 seconds) |

**Table 2: The experimental light-curing modes used in this study [9].**

| Light-curing mode | Regimen |
|---|---|
| Prolonged low-intensity pulse cure mode (PLPC) | 100mW/cm2 → Delay → 300 mW/cm2 (20 seconds) (10 seconds)(120 seconds) |
| Prolonged moderate-intensity pulse cure mode (PMPC) | 100mW/cm2 → Delay → 400 mW/cm2 (20 seconds) (10 seconds) (90 seconds) |
| Rapid high-intensity continues cure mode (RHCC) | 600mW/cm2 (60 seconds) |

## DISCUSSION

The findings of this study are in agreement with that of Yap et al. [7] who stated that, regardless of the curing mode and composite type, the composite continued to shrink after removing the light source. This can be attributed to the post-curing of composite resins. It was found in this study that, there was a sudden jump in polymerization shrinkage strain at 1-minute post-curing time with most of the curing modes and with all the composite types and this jump was minimized in PLPC and PMPC curing modes due to the slow and gradual polymerization with these two curing modes. This jump in polymerization shrinkage strain at 1minute post-curing time might be of special clinical significance during the first minute, when the tooth-bonding agent-restorative interface is immature, as the amount of polymerization shrinkage strain might affect the restoration's marginal integrity during this very initial time of the restoration's life. Thus, problems associated with adhesion loss often start during this early stage of cure, occasionally even before the patient has left the dentist's chair and this is in agreement with the findings of Dauvillier et al. [10]. In this study, Herculite XRV light-activated composite exhibited mostly the highest shrinkage strain with all the curing modes and all post-curing time followed by Tetric Ceram, Degufill Mineral and Heliomolar, which exhibited the lowest shrinkage strain except for RHCC curing mode where, Degufill Mineral exhibited higher shrinkage strain than Tetric Ceram till one minute post-curing time where the two composites exhibited approximately similar shrinkage strains up to 60 minute post-curing time. A strong correlation between filler loading of commercial composites and their elastic modulus or stiffness has been demonstrated [11]. It appears that the greater stiffness of the more heavily filled composites plays a major role in determining the amount of polymerization stress produced [12]. The general reduction in polymerization shrinkage strains of the four different composites in PDI, PDII, SS, PCI and PCII curing modes at 60-minute post-curing (Figure 5) in relation to the control-curing mode (of a comparable energy density) could be attributed to the effects of both pulse activation and soft-start polymerization (ramped curing) and especially with PDII curing-mode, which is generally exhibited the lowest polymerization shrinkage strain for all the four light-activated composites at the end of curing, 1-min post-curing, 5-min post-curing and 60-min post-curing (Figures 2-5). The use of a low initial light energy density for a relatively long period, allowed for prolongation of the pre-gel stage [7] and a larger portion of the overall shrinkage might be compensated by flow and stress at the cavity margin might be reduced.

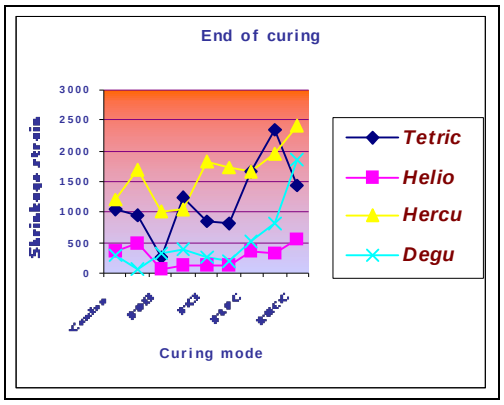


**Figure 2: Mean polymerization shrinkage strain in micro-strain of the tested composites at the end of curing.**

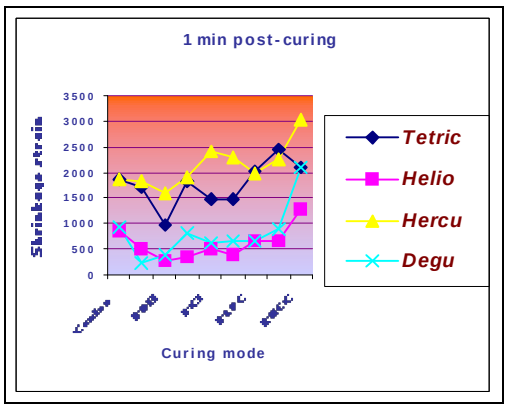


**Figure 3: Mean polymerization shrinkage strain in micro-strain of the tested composites 1-min post-curing.**

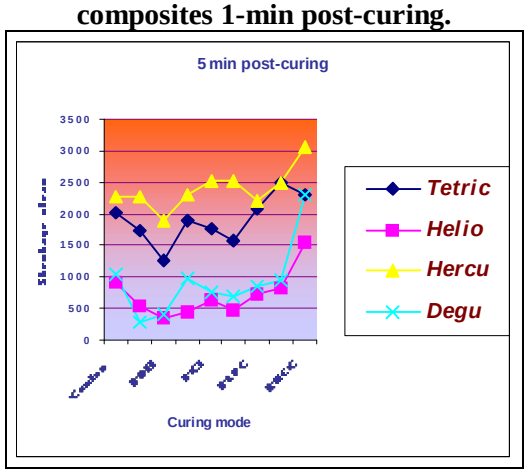


**Figure 4: Mean polymerization shrinkage strain in micro-strain of the tested composites 5-min post-curing.**

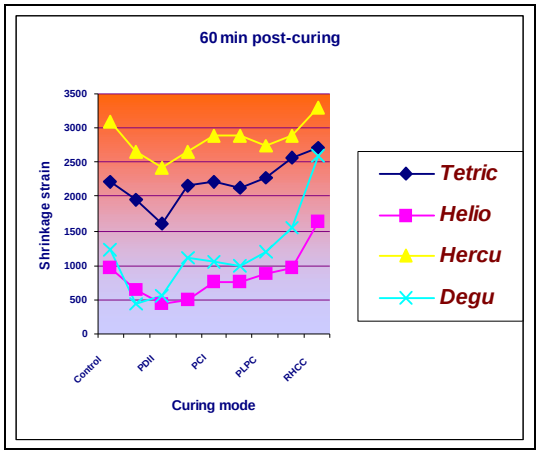


**Figure 5: Mean polymerization shrinkage strain in micro-strain of the tested composites 60-min post-curing.**

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